Method for Operating a Synchronous Machine

The present invention relates to a method for operating a synchronous machine which comprises a permanently excited rotor and a stator provided with phase windings, in which the rotor position is determined. Further, the invention relates to a method for operating a synchronous machine comprising a permanently excited rotor and a stator provided with phase windings which is connected to an actuation electronic unit including a data memory for rotor position values, wherein the rotor position values stored in the data memory are read out.

Published patent application DE 103 11 028 A1 discloses a method for determining an initial rotor position and rotational speed upon pulse release of a permanently excited synchronous machine which is fed by a converter and has no position indicator and speed transmitter. In the prior art method, first the rotor position after the start of the synchronous machine is detected, and this procedure is repeated after a predetermined time. As this occurs, the rotational speed of the synchronous machine is detected in addition. However, when determining the rotor position, errors may occur which are encountered in the entire further operation of the synchronous machine, because it is not envisaged to check the rotor position values found. This is considered a shortcoming.

In view of the above, it is a first object of the invention to disclose a method which eliminates errors and in particular angular errors when the rotor position is determined. A second object of the invention is directed to disclosing a method which eliminates errors and in particular angular errors of the stored rotor position value.

According to the method, the first object is achieved in that for the correction of a possible angular error, with the synchronous machine unloaded, at least one current and/or voltage vector having a defined duration is applied to the phase winding in the direction of the determined rotor position. Such a measure constrains the orientation of the rotor of the synchronous machine in the corresponding angular position.

A particularly favorable improvement provides that the relative change of the rotor position is determined by means of a sensor element synchronously with the application of the at least one voltage or current vector.

In another favorable improvement, the relative change is taken into consideration in an additional determination of the rotor position.

Square-wave voltage pulses are applied to the phase windings when the rotor position is determined. It is provided in this arrangement that any possible relative change of the rotor position is determined with a sensor element synchronously with the application of the square-wave voltage pulses.

In a particularly advantageous embodiment, additional current and/or voltage vectors are applied in angles differing from the current rotor position, and that the indicator of the relative change of the rotor position is used as a criterion for judging the ease of motion (no-load condition) of the synchronous machine.

Still another favorable improvement of the method of the invention provides that the current vector which develops due to the application of the voltage vector is determined by means of a current measuring device and is used as a criterion for judging the condition of the electrical connections of the phase windings.

The second object of the invention is achieved in conformity with the method because at least one current and/or voltage vector with a defined duration is applied to the phase windings in the direction of the stored rotor position for the purpose of correction of a possible angular error in an unloaded synchronous machine. This measure constrains an orientation of the rotor of the synchronous machine in the corresponding angular position.

It is arranged for that prior to the reading out of the rotor position value stored in the data memory, a check is made whether the rotor was secured against rotation by means of an anti-rotation mechanism since the last storing of the rotor position value.

In a favorable improvement, the relative change of the rotor position is determined by means of a sensor element synchronously with the application of the at least one voltage

or current vector, and the indicator of the relative change of the rotor position is used as a criterion for the quality of the stored rotor position values.

Further, it is provided that the current vector which develops due to the application of the voltage vector is determined by means of a current measuring device and is used as a criterion for judging the condition of the electrical connections of the phase windings.

The invention will be explained more closely in the following making reference to the accompanying drawing, the only Figure of which refers to a block diagram showing a device for implementing the above-mentioned method of the invention.

The synchronous machine 1 illustrated in Figure 1 includes a stator which is equipped with a symmetric, two-pole and three-strand three-phase winding. A rotor cooperating with the stator is formed of a permanent magnet. Besides, associated with the synchronous machine 1 is an actuation electronic unit 2 which includes a data memory 6 for rotor position values and further memory values such as controller and machine parameters. The actuation electronic unit 2 includes an actuation software module 3 and an output stage 4 into which a current measuring device is integrated. The voltage signals of the output stage 4 are applied to the phase windings U, V and W of the synchronous machine 1. The output signals $\Delta\phi$ of a relative rotor position sensor 5 being representative of a rotor position change of the synchronous machine 1 are sent to the above-mentioned actuation software module 3.

In previously known methods for determining the rotor position, the rotor position values are not checked for their correctness, and the further operation of the synchronous machine 1 is continued using the rotor position values afflicted by uncertainties. The method of the invention suggests that after a determination of the rotor position, with the synchronous machine 1 unloaded, at least one current or voltage vector is applied by the output stage 4 into the phase windings U, V and W in the direction of the determined rotor position. This measure is used to align the rotor in the angular position predetermined by the applied current or voltage vector. It is thereby ensured that the rotor adopts the previously determined angular position. Synchronously with the application of a current or voltage vector as described above, the relative rotor position sensor 5 senses the relative change of the rotor position performed during the alignment, should the determined rotor position differ from the actual rotor position. This relative change $\Delta\phi$ of the rotor position is sent to the actuation software module 3 and taken into consideration in a further determination of the rotor position, because the relative change $\Delta\phi$ is included in a correction function. This correction function is employed with respect to the determined rotor position values in a new determination of the rotor position. This measure allows performing an additional determination of the rotor position at a higher rate of precision.

The change of inductance of the phase windings U, V and W, which is caused by the rotor movements, is determined in the above-mentioned determination of the rotor position. This is done by applying square-wave voltage pulses to the phase windings U, V and W. Simultaneously, the course of the current

I_U, I_V, and I_W flowing through the phase windings U, V, and W is detected by the current measuring device in the output stage 4 and sent to the actuation software module 3. The position of the rotor can be deduced from the current variation I_U, I_V, and I_W. When the position of the rotor is changing, the course of the current which flows through the phase windings will change as well. In addition, any possible change of the rotor position is sensed by means of the relative rotor position sensor 5 synchronously with the application of the square-wave voltage pulses and is also sent to the actuation software module 3.

Additional current or voltage vectors in angles different from the determined rotor position are applied by the output stage 4 into the phase windings U, V, and W of the synchronous machine 1 when the synchronous machine 1 is unloaded, that means when the synchronous machine 1 is at standstill. The relative change of the rotor position is determined simultaneously by the relative rotor position sensor 5. As this occurs, the indicator of the relative change of the rotor position is a criterion for the ease of motion of the synchronous machine 1.

Further, the condition of the electrical connections of the phase windings U, V, and W of the synchronous machine 1 is judged. This is done because the current vector, which develops due to the application of the voltage vector, is determined my means of the current measuring device in the output stage 4. If the determined current vector has an angular position different from the introduced voltage vector, it must be assumed that a least one of the electrical connections of the phase windings U, V, and W is inoperative.

Besides, the electrical resistance in the phase windings U, V, and W is detected by way of the amount of the current vector.

If a determination of the rotor position is not provided, but the operation of the synchronous machine 1 is performed by means of rotor position values stored in the data memory 6 of the actuation electronic unit 2, according to another method of the invention, at least one current or voltage vector with a defined duration is applied to the phase windings U, V, and W in the direction of the stored rotor position. The result is that the rotor is aligned in the angular position predefined by the applied current or voltage vector, and it is safeguarded that the rotor actually adopts the stored angular position. The relative rotor position sensor 5 senses the relative change of the rotor position performed during the alignment synchronously with the above-described application of a current or voltage vector, should the determined rotor position value differ from the actual rotor position. This relative change $\Delta\phi$ of the rotor position is sent to the actuation software module 3 and represents a criterion for the quality of the rotor position values stored in the data memory 6 of the actuation electronic unit 2. Further, the relative change $\Delta\phi$ is a criterion for the quality of all memory values such as controller and machine parameters stored in the data memory 6.

The safe putting into operation of the synchronous machine 1 is further improved in that prior to the reading out of the rotor position value stored in the data memory 6 of the actuation electronic unit 2, a check is made whether the rotor was secured against rotation by means of an anti-rotation mechanism since the last storing of the rotor position value.

It is expected in this case that an application of a current or voltage vector in the direction of the stored rotor position will not cause a relative change of position of the rotor. This is determined using the relative rotor position sensor 5, as has been described hereinabove.

In this method, too, the condition of the electrical connections of the phase windings U, V and W of the synchronous machine 1 is judged. The current vector which develops due to the application of the voltage vector is determined by means of the current measuring device in the output stage 4. If the determined current vector assumes an angular position different from that of the applied voltage vector, it must be assumed that at least one of the phase windings U, V and W is not connected to the output stage 4. Besides, the electrical resistance in the phase windings U, V and W is detected by way of the amount of the current vector.